Player strategies: achieving breakthroughs and progressing in single-player and cooperative games

Conference or Workshop Item

Player Strategies: Achieving Breakthroughs and Progressing in Single-player and Cooperative Games

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ABSTRACT
Challenge is considered to be one of the key components of game-play, where game designers face the tricky task of getting the balance right so that game-play is neither too easy nor too difficult. Through attempting in-game challenges, players experience cycles of breakdown and breakthrough, where breakthroughs involve moments of insight in which learning occurs. However, little attention has been given to how players actually overcome challenges to progress during game-play. Across two studies, we explore the ways in which players attempt to achieve breakthroughs in relation to single-player and co-located multiplayer games. We identified a number of strategies that are used by players, which illustrate how learning occurs during play. For instance, while "*Experiment*" involves forming an informal hypothesis, "*Trial & error*" occurs when the player tries to find out what, if anything, will happen when they carry out an action. These strategies are considered in relation to supporting player progress and engaging game-play when designing commercial and educational games.

Author Keywords
Games; learning; engagement; player strategies.

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H.5.3 Information interfaces and presentation (e.g., HCI): Miscellaneous ; K.8.0. General: Games.

INTRODUCTION
Digital games now appeal to large audiences of both "hardcore gamers" and more "casual" players [17] and are being produced for a variety of purposes including entertainment and education. However, despite their increasing popularity, creating a successful game is not an easy task - up to 80% of titles fail commercially [12]. Further, while it has been argued that learning is what makes games fun [18], outside the realm of education, there has been little examination of how players learn during play and how this relates to the experience of achieving game progress. Investigating these processes will not only improve our understanding of learning but is also likely to contribute to the design of more engaging educational and commercial games.

Within the field of HCI, games research has focused mainly on enjoyment in digital games, e.g. [24], and on how to evaluate game-play experiences, e.g. [25]. Learnability is sometimes considered in relation to design, e.g. [2], but rarely beyond the scope of grasping initial controls and mechanics. Furthermore, while cognitive challenge is considered a key component of game-play [5; 23] and there has been some consideration of how learning results from game-play breakdowns [14; 16; 26], little attention has been paid to the different strategies adult players employ to overcome game play obstacles.

This paper addresses this issue through reporting on two studies. A preliminary analysis of the first study was previously reported as a work-in-progress [15]. Participants played two different games for up to 20 minutes each and the data collected was used to develop a standardized set of strategy types that players employed to overcome breakdowns during play. This paper also presents a second study; in which pairs of players played a cooperative game for up to 40 minutes. The analysis also extends the initial strategies in order to account for multiplayer co-located play and learning within a social context. The findings of both studies are drawn together and considered in terms of game design implications.

RELATED WORK

Learning and games
Gee's seminal book on video games [8] lays out numerous ways in which well-designed games are able to support learning. Essentially, Gee argues that through increasing rewards and scaffolding progress, games are able to push players "to operate within, but at the outer edge of, his or

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her resources, so that at those points things are felt as challenging but not 'undoable'" [p. 71; ibid]. In this way players are continuously learning, practicing and mastering skills, and adapting their knowledge to deal with the challenges presented to them. Further, Gee notes how game knowledge and meanings are distributed across objects, tools, technologies and other players.

Gee [8; 9] is mainly concerned with games as a metaphor for learning in the digital age, and how education can learn from commercial game design. However, his semiotic analysis is based on his own observations so there is a need for further empirical evidence to substantiate his account.

Game-play breakdowns and breakthroughs

A range of work has examined breakdowns that occur during game-play. For instance, Pelletier and Oliver [26] point out that while Gee [8] provides a strong account of how learning may occur, it is not clear what researchers should focus on if they do want to study game-play. As a result, they present an approach based on Activity Theory [19], where player activities were decomposed into actions and operations, with particular attention paid to "contradictions" within the activity system. "Contradictions" refer to problematic moments that occurred during play, such as failures or mistakes i.e. breakdowns. The authors studied 3 cases (one involving *Harry Potter & the Chamber of Secrets*; the other two *Deus Ex*). Their analysis enabled an identification of the strategies players adopted (such as "spot unusual objects and click on them") but relying on observation alone meant inferences were made about player objectives. Further, the aim was to present a method for studying game-play rather than generalisable findings so it is unclear how applicable the strategies they identified are to other contexts.

Ryan and Siegel [27] also focus on breakdowns as a way to understand game-play, relying on a previously identified distinction between *interaction* and *illusion breakdowns* [22]. Breakdowns are described by Ryan and Siegel as occurring when actions carried out by players no longer seem to work; where breakdowns in interaction refer to "natural breakdowns" that lead to new strategy development, and breakdowns in illusion refer to a loss of immersion (in terms of absorbed attention). They argue that the former are part of normal game-play, but unlike the latter, they do not disrupt the experience of flow. Flow [6] occurs when there is an appropriate match between someone's skills and the challenge presented to them, resulting in an experience of intense engagement.

As a result of their heterophenomenological analysis across 17 games, Ryan and Siegel [27] present four main categories of breakdown and 17 heuristic guidelines for design. The categories relate to Perceiving the Environment, Developing Strategy, Taking Action, and Meaning Making. An example guideline under Developing Strategy is: "Keep tasks and instructions focused towards the current goal." However, while certain player strategies are implied, e.g. trial and error, this was not their focus.

The concept of breakdowns has also been utilized in other design contexts. For instance, as part of research that elicited educational mobile technology requirements, Sharples [29] defines breakdowns as "observable critical incidents where a learner is struggling with the technology, asking for help, or appears to be labouring under a clear misunderstanding" and adds the concept of breakthroughs: "observable critical incidents which appear to be initiating productive, new forms of learning or important conceptual change" (p. 10).

These concepts have been modified in order to investigate the relationship between learning and involvement within game-play. Iacovides and colleagues argue that breakdowns and breakthroughs can occur in relation to player *action* (e.g. problems with the controller, performing a new attack); *understanding* (e.g. not knowing what to do next, figuring out a solution a puzzle); and *involvement* (e.g. getting frustrated, experiencing satisfaction) [14; 16]. While this approach provides a more nuanced appreciation of how learning and involvement relate to each other, the research reported by Iacovides and colleagues does not explicitly consider the different strategies players adopt in attempting to overcome breakdowns and achieve breakthroughs.

Problem-solving and player strategies

There has also been some interest in problem-solving in games and the strategies players adopt from a psychological perspective. For instance, Blumberg et al. [4] conducted a think-aloud study that examined how frequent and infrequent players negotiated impasses within *Sonic the Hedgehog 2*. The authors describe an impasse as "a catalyst for the acquisition of new knowledge and problem-solving strategies" while games are described as a venue for examining the specific problem solving strategies that facilitate 'expert' performance during game play" (p. 1531). They found that frequent game players generally made more references to insight and game strategies than infrequent players, though all players tended to comment on game progress and potential game strategies after reaching an impasse. While their study indicates that expertise may lead to different kinds of problem solving, the strategies used by players were not classified during the analysis so it is unclear how they actually overcame impasses.

In order to investigate the strategies novices adopt when playing a new game (*Return of the Incredible Machine: Contraptions*), Alkan & Cagiltay [1] integrated eye-tracking equipment within a usability study. Perhaps unsurprisingly, the results indicated fixation times were lowest in relation to the menu and highest in the area where participants had to focus on solving problems. During the post-play interview, participants suggested the main strategies they use to learn games are "trial and error" and using "friends as sources of information". No serious usability issues were uncovered though the authors note that while the game offers a hint function that provides explicit instructions to the player, these were never heeded by the participants. This suggests that players do not always pay attention to help provided by the game, though, given that the participants reported that they "prefer more complex action and strategy games" (p. 541) they may have found the instructions boring and preferred to ignore them.

The previous studies mentioned have focused on single-player games. Adopting a different emphasis, El-Nasr et al. [7] present a method for evaluating cooperative game design. While not explicitly focusing on player strategies, some of Cooperative Performance Metrics (CPMs) presented suggest certain types of strategies that occur during cooperative play. These include examples such as "Worked out strategies" (where players discuss how to solve problems, divide up game zones, and/or consult each other while navigating the game world) and "Helping each other" (where players discuss controllers and game mechanics, dictate how an obstacle should be overcome, and/or rescue a player who is failing). However, these metrics are presented as a tool for evaluating game-play in relation to cooperative design patterns, not for understanding how learning occurs in relation to the player. For instance, other CPM examples are "Laughter or excitement together" and "Got in each other's way".

While the research discussed above has examined the challenges and problems that can occur during play, it lacks comprehensive investigation into the variety of strategies players adopt to overcome challenges across different games. In order to further explore these issues, we describe two observational studies of game-play (supplemented by post-play interviews) that explore learning in the form of the different types of strategies people adopt within single-player and multi-player contexts.

STUDY 1

Method

Design: This was an observational study of game-play that included a post-play interview, where a recording of the game-play session was reviewed by participants.

Participants: Twenty participants (F=5; M=15; Mean age = 25.2) were recruited from a university participant pool. Participants were paid £10 for taking part, and consisted of an equal mix of hardcore and casual players so that the strategies would reflect a range of player ability. Hardcore players are those who have played a large number of games, invest large amounts of time and resources towards games, and enjoy higher levels of difficulty, while casual players play fewer games, commit little time and few resources towards games and prefer lower levels of difficulty [17]. Player categorization was established through a combination of self-identification and a brief questionnaire about their gaming habits and preferences.

Materials: Each participant played two games of different genre, to improve the generalizability of the research. Both games were sourced from Independent Games Festival finalists [13] to ensure they had a reasonable level of quality and that, being independent games, it was unlikely that participants would have played them before.

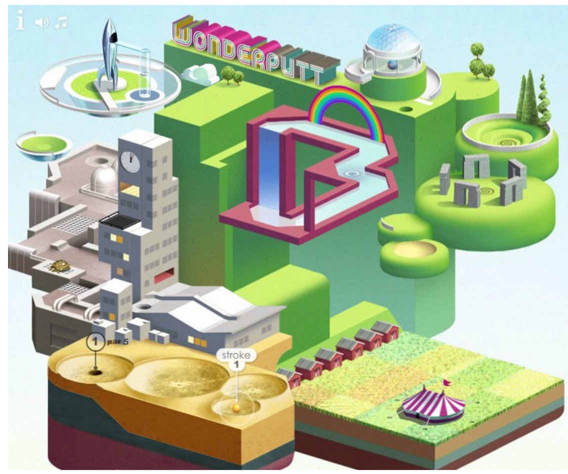

Figure 1: Screen shot from *Wonderputt* (2012 finalist)

Wonderputt (*WP*) is a crazy golf game (Figure 1). The player completes 18 holes using the mouse to adjust the angle and the speed of the ball. The holes gradually get harder requiring more precision and creative approaches.

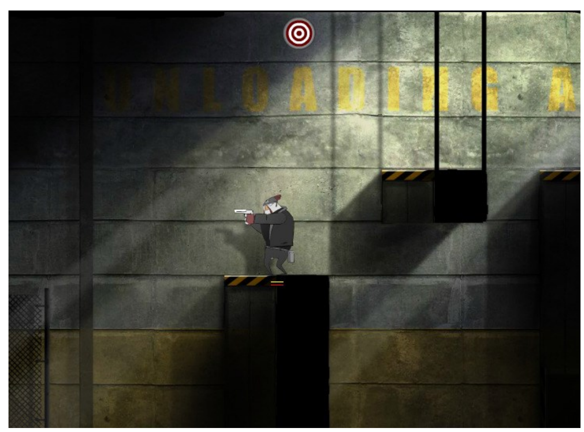

Figure 2: Screenshot from *Rocketbirds: Revolution!* (2010 finalist)

The second game, *Rocketbirds: Revolution!* (*RR*), is a 2D third person action/strategy game, where the player has to negotiate their way through an enemy base end of the level solving basic puzzles, killing enemies and managing their health and ammunition (Figure 2).

RR and *WP* are web-based games, which means they were accessible and did not require extended tutorial sessions to acquire basic proficiency. This was ideal as it ensured that players could become familiar with the gameplay mechanics within a short space of time. Simple instructions sheets were also provided.

The gaming session was recorded on a high definition video camera positioned on a tripod behind the participant, which captured the participant's interaction with the game. The post-play cued interview was recorded using the iPhone memo software and a computer monitor was used to play the gaming session back to the participant.

Procedure: Participants were given the same instructions and played through the same two games, counterbalanced in order over two sessions (split to minimize the effects of fatigue). During the first session, participants completed a questionnaire about their gaming habits and preferences. They were then provided with a brief overview of the game and were given 20 minutes to play (unless they finished the game earlier). At the end of the session, the experimenter interviewed the participant and played back a recording of the game-play session to stimulate their recall [as in 14]. During this time, the participant was asked to explain what they were doing and thinking with particular emphasis placed on how they dealt with the problems they encountered during the session.

Analysis

The video and interview data was coded for critical incidents. An incident was defined as a point in the game where the participant found themselves in a situation where they were unable to progress through lack of proficiency with the controls (action breakdowns), a lack of understanding about their current objective (understanding breakdowns) or reduction of their level of interest in the game (involvement breakdowns). In addition, any significant changes in a participant's strategies were also recorded even when this change in behavior was not accompanied by a breakdown. In order to develop the categories of strategies, these incidents were then examined in relation to the actions the player took to overcome breakdowns and achieve breakthroughs. Similar to a thematic analysis [3], the strategy categories were developed iteratively in a bottom up approach and discussed among the researchers until a definitive set was able to account for all different actions observed.

Findings

Player strategies

The strategies are defined below with examples provided for illustrative purposes. Participants are referred to by number e.g. Participant 1 is P1.

1. Trial & error

This approach consists of exploring what the game allows, how to carry out actions and finding out which actions lead to progress. Essentially, after carrying out a specific action, the player is trying to find out what, if anything, will happen. For instance, P10 (Hardcore) in *RR* is having trouble picking up a key, so resorts to pressing different buttons on the keyboard to find out whether any translate to in game-actions. Similarly, P2 (Casual) in *WP*, did not know what to do next so tried hitting the ball hard against the rocks to see what would happen. In this case, the action resulted in deactivated a force field, allowing for further progress. While P2 learnt from this experience, P8 (Casual) on the same level accidentally caused the force field to deactivate when repeatedly aiming at the hole, but failed to notice what had occurred. For P8, *Trial & error* was not accompanied by an understanding breakthrough and subsequent progress was accidental.

2. Experiment

On the basis of previous knowledge and/or understanding breakthroughs resulting from *Trial & error*, the player forms an informal hypothesis, takes a subsequent action and, depending on the outcome, either proceeds in the game or reforms the hypothesis. For instance, after taking an exploratory shot (*Trial & error*) to see how the crane works in *WP*, P19 (Casual) uses this information to direct his next shot and is able to use the crane to progress within the level. This strategy can also involve transferring knowledge from the real world, from experiences with other games or from earlier experience within the same game. For example, in *WP*, P7 (Casual) realizes the ball needs to cross a section of water. Through their understanding of real world physics, they assume they will need to hit the ball harder than normal so that it will skim over the water and this approach proves successful. However, inappropriate transfer can lead to further breakdowns. For example, in *RR*, P6 (Hardcore) misses several jumps by assuming the character will grab onto a ledge automatically as in the case of *Mario* and *Zelda* games.

3. Repetition

Initially called *Practice* [15], this strategy was renamed to cover both when a player's aim was to gain proficiency with the controls (and so rehearsed or refined a technique on an obstacle or in a safe area of the game) and when they proceeded to repeat the same action several times in an effort to progress. For instance, in *RR*, P14 (Casual) decides to practice within the first screen of the game, where there were no enemies and no risks. They gain basic proficiency in moving, jumping and firing the gun before proceeding with the level. Similarly, in *WP*, P3 (Hardcore) knows that the only way to proceed is to hit the ball up the hill, so they attempt the same shot several times until they succeed.

4. Stop & Think

Play is suspended briefly (either by pausing or not acting within the game) while the player considers how best to proceed. While reflection may occur "in action" as part of the *Experiment* strategy, this category is reserved for reflection "on action" [28]. For instance, in *RR*, P12 (Hardcore) accidently unequipped their gun so when they came across an enemy they were unable to return fire. They retreat to the previous screen and pause to consider what has gone wrong. A variant of this strategy involves pausing the game to check for external resources or to look for in-game help. For instance, in *WP*, P4 (Hardcore) looks at the information sheet provided to find out more about the controls work. Similarly, P15 (Casual) in *RR* initially consults the information sheet before attempting to practice different combinations of actions (*Repetition*).

5. *Take the Hint*

Games often provide explicit hints and tips at various points in the game – this strategy involves the player choosing to carry out the suggested action. In *WP*, this was only observed at the introduction screen when players would attempt to interpret the arrows provided to them on screen and translate them to the mouse controls. In *RR*, hints are provided at various points e.g. the player is told they can hide behind certain objects in the environment. However, further breakdowns can occur if the player misses these instructions or does not understand them. For instance, P15 (Casual) in *RR* does not notice the hint about using the action button to access the lift and ends up exploring other parts of the game for clues instead.

Discussion

The findings illustrate how multiple strategies were often employed to achieve a single breakthrough, as one would lead on from the other. For instance, while a player would start exploring the game through *Trial & error,* knowledge would be gained via understanding breakthroughs that fed into the *Experiment* strategy. Alternatively, action breakdowns as a result of *Trial & error* could lead to *Repetition* as players aimed to develop their abilities. *Stop & think* tended to occur after repeated breakdowns and the failure of other strategies. In contrast, *Take the hint* usually led to breakthroughs without breakdowns but only if the hint was noticed in the first place.

However, as these strategies were developed on the basis of single-player games, it is not clear to what extent they would apply when people are playing a game together. This is important to consider as the "people factor" [20] is a key reason for why we play games. Gameplay can be an inherently social phenomenon and as Stevens and colleagues argue [30], multiplayer games allow for additional opportunities for learning and engagement to emerge from the interactions between players. Social factors are especially important to consider given the popularity of co-located games [7].

In addition, while breakdowns are an important source of learning, it was also clear from the analysis in Study 1 that player strategies could lead to breakthroughs without a preceding breakdown. As such, study 2 aims to validate the existing strategies and extend them in relation to breakthroughs that occur during co-located play.

STUDY 2

Method

Design: An exploratory case-study approach was [31] employed where multiple pairs of participants were observed playing a co-located cooperative game for approximately 40 minutes. The participants were interviewed briefly about their experience after the session. A recording was not played back as the conversation between participants provided a rich source of data.

Participants: 11 pairs were recruited for the study (M= 20, F = 2; Mean age = 25.9). Participants were paid £10 each for taking part and recruited from a university participant pool, and from advertisements placed around campus and video game shops. The adverts asked for participants to bring in someone they felt comfortable playing with and had played with before. A screening questionnaire was used to assess how experienced players were with of the game being used in the study, *Portal 2.* Participants were classed as experts if they had played a game in the *Portal* series before or had experience of the cooperative mode in *Portal 2.* Novice participants were those who had limited or no experience with the series. In total, there were 5 pairs of Experts, 4 pairs of Novices and 2 Mixed pairs (containing one expert and one novice). As in Study 1, a mix of players were included so that the strategies would reflect a range of player ability.

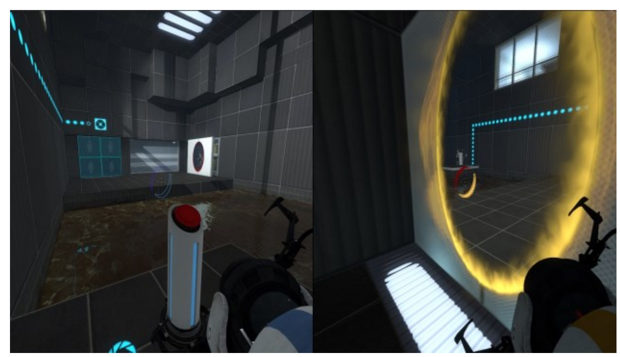

Figure 3: Screenshot of *Portal 2* spilt screen

Materials: Portal 2, was created and published by Valve and is available through the Steam gaming platform. The game employs a 3D first-person perspective, where players have to overcome a variety of puzzles in self-contained 'test chambers' using portals. The portals, projected on surfaces with a "portal gun", create a pathway that allows players to cross between spaces instantly. The levels often contain hints via visuals on the ground and walls, while the voice of GLaDOS (Genetic Lifeform and Disk Operating System), a robotic AI, sarcastically directs and berates the players within each chamber. The participants were asked to play through three different sections of the game:

1. *Calibration Course*: This tutorial level introduces players to the basics of playing in cooperative mode,

including an in-game communication method called the "Ping tool", with which players can point at place of interest and "ping" to draw attention to it.
2. *Team Building (Sections 1-3)*: This is the first level in which players have to work through a number of test chambers that require team work and the use of portals.
3. *Friendship is Magic 3*: *Portal 2* has an active online community where people create and share their own test chambers using the games inbuilt tools. This map was rated easy-medium difficulty and 5/5 stars by 8334 players. Including a custom test chamber ensured that even experienced players would be playing something they had not done before.

The sessions took place in a lab that was furnished like a living room, containing a comfortable sofa, coffee table and TV. The game was running on an Intel i5 gaming PC with a dedicated graphics card. The PC was connected to a large screen LCD TV where the game was presented in a split screen format (Figure 3). Participants interacted with the game via wireless Xbox 360 controllers. A camera was placed above the TV to capture the participants sitting on a sofa and a microphone was positioned on a table in front of the sofa. Morae Recorder by Techsmith was used to capture the game-play feed from the PC.

Procedure: Piloting with three pairs before the main study ensured that an appropriate custom community map was selected and that the game was playable by players with varying experience. Novice pairs had more trouble with some of the core mechanics so a more detailed information sheet was supplied. In the main study, participants were introduced to the game, before starting the calibration course. The experimenter observed the session from a separate room and took note of important events that occurred. The participants were stopped after completing the three sections, or until 40 minutes had passed. After the session a brief semi-structured interview was conducted to review and discuss some of the key events that occurred.

Analyses

The primary source of data was the video recordings, synchronized with game footage of the participants playing the game and talking to each other. This data was supplemented by the post-play interviews.

This study focused on critical incidents where breakthroughs occurred. These related to action (when the player performed a new action via the controller), understanding (when a participant realized how to progress in the puzzle or learnt about a game mechanic), and involvement (when participants were visibly happy or interested in the game). The strategies developed in Study 1 were applied but it was soon found that they did not account for all aspects of cooperative co-located play. Similar to a thematic analysis [3], new categories were developed iteratively, in a bottom up approach and discussed among the researchers until a definitive set was able to account for the different actions observed.

Findings

Short examples of the initial strategies are provided for illustrative purposes, before presenting the cooperative strategies. Participants are referred to as P1 or P2 (referring to Player 1 and Player 2 within a single pair) in "Session X", where X denotes which session the pair took part in.

Initial strategies

1. Trial & error

As in Study 1, *Trial & error* was coded when players explored the game environment and mechanics. This strategy was also found to be source of fun for the players and applied without a specific goal in mind. For instance, after starting the final map, P2 in Session 1 (Mixed), places a portal on the ceiling and floor and jumps through them, creating a continuous loop. P1 notices this and says "What happens if I jump in with you?". After doing so, for a short while they are both falling through the portals, before crashing into each other. They laugh and then continue with the game. While there is no initial breakdown in this case, arguably the players are experiencing an involvement breakthrough as they probe how the game works.

2. Experiment

Experiment was evidenced in a co-located setting through players thinking out loud and referring to transfer of knowledge. For instance, in Session 7 (Expert), after entering a new area where a receptacle drops from the ceiling after pressing a button, P2 wonders "If I press this [the button], will that one [the receptacle] go?". He proceeds to press it again and watches while the previous receptacle disappears and a new one drops from the ceiling. This is a recurring mechanic in the *Portal* games, where only one item is allowed at a time, and it is something P2 appears to be aware of but wanted to test out.

3. Repetition

Repetition was usually utilized in *Portal 2* when players were trying to get a sequence of tasks correct or to get the timing of certain actions right. An example of this occurred in Session 2 (Expert), where P1 pressed a button to release a cube that drops into a body of water. P2 was not able to catch it in time so says "You've got to do it again, I missed it". P1 then presses the button a couple of times until P2 is able to grab the cube before it disappeared into the water. They are then able to proceed to the next task.

4. Stop & think

The *Stop & think* category was most commonly coded when one player would stop playing in order to observe the other. For example, in Session 11 (Expert), the players encounter a problem in the custom community map which requires them to split off to perform different tasks. They were initially in the same room, but soon realize that one of them needs to investigate the effect of their action within another room (since there is no direct line of sight). P1 ventures out to the other room while P2 is inactive and focuses solely on P1's screen. As one player investigates the environment, the observer chimes in with suggestions e.g. referring to the location of P1's portals "No wait, from the other side? … Oh, no, there." (P2).

Similar to Study 1, participants would also occasionally consult the information sheets provided about the game. For example, in Session 7 (Expert), P1 stops to check the sheet and tells P2 what the Ping button is. The post-play interviews corroborated the fact that players would sometimes consult external resources, e.g. an online guide, when they got stuck playing games outside of the lab.

5. Take the Hint

Portal 2 contains many hints in the environment. For instance, in Figure 4, the symbols on the ground indicate that the button will release a cube from the ceiling but that the player should watch their head! However, players rarely seemed to refer to these pictorial clues, and it is not clear whether they actually paid attention to them or not. Arguably, these hints would be easier to interpret only after having had some experience of playing the game.

Figure 4: Screenshot of floor symbols in *Portal 2*

The Calibration course was designed to introduce players to the basic game mechanics. However, particularly for those who had not played the Portal series before, the instructions were not always clear. For instance, in Session 9 (Novice) while P1 understood the instructions for getting his avatar to wave, P2 was confused, until P1 showed him what to do. Similarly, in Session 6 (Novice) players had trouble using the "Ping Tool", not realizing it was for communication and confusing it with their portal guns.

Cooperative strategies

The additional strategies identified within the data set are defined below with illustrative examples.

6. Knowledge exchange

Players often chatted about the game challenges and environment, providing feedback about what they are doing, through sharing (and sometimes arguing!) about the knowledge and ideas they gained from other strategies such as *Trial & error* and *Experiment*. For instance, in Session 9 (Novice), P1 and P2 are trying to figure out how to cross over a pool of water and go through a timed door. The solution involves one of the players staying behind to control the door timer while the other player crosses over and creates portals for the player left behind. P1 and P2 are in a constant conversation, asking each other questions and sharing ideas e.g. P2: "Yeah, create a portal there", P1: "But then you can't press the button". The ensuing discussion leads P2 to achieve an understanding breakthrough and then to dictate the solution to P1 in the form of *Guidance* (see below).

Another example of this strategy concerns how players would split up to explore the game. Though *Portal 2* sometimes enforces a division of labor to solve puzzles, there were occasions when players would divide up responsibility when they didn't have to. For instance, in Session 3 (Expert), the players need to align a cube with a laser beam but are having trouble doing so. P1 goes to the cube and re-aligns it slightly asking P2 to go over the far node to provide feedback about how close the laser is.

7. Guidance

This category refers to instances where a player directly asks for help, or where one player explicitly provides guidance in the form of dictating instructions. For example, in Session 4 (Novice), P2 asks P1 "What should I do?"; P1 tells P2: "you see, first here, and then first out here, and then go in here and last here [He pings at the walls whilst saying this and continues with more explicit instructions] …Ok so, first cancel all of them…you create one here and uh, here [pings at the location he wants the portal]". In this instance, P2 follows the guidance and they finish the puzzle successfully.

As the last example also indicates, the "Ping Tool" was sometimes used by players. However, given that they were in a co-located environment, players would often resort to physical gesturing and pointing to provide emphasis. For instance, in Session 8 (Novice), during the 'Calibration Course', both players are confused about how to get up to a ledge. P2 starts describing a solution, eventually standing up and pointing at the TV screen to illustrate what needs to be done:

P2: "So shoot the thingy and then look at me, in front of me there is a… there is something you can…"
[P1 fires portal at incorrect place]
P2: "No, not in front of me, in front of…. [Stands and walks to the TV] You should shoot here…if you shoot there you can go up".

8. Surrender control/take over

Unlike *Guidance* where advice is offered verbally, this strategy involves a physical taking over of control by one of the players. This included occasions where one player would allow the other to take the controller - e.g. in Session 5 (Expert), P2 asks P1 beforehand: [Laughs] "Do you want me to do it?" (referring to making a selection with the "Ping Tool"). However, there also were also occasional yet nonetheless surprising examples when taking over occurred without permission. For instance, in Session 6 (Novice), P1 was waiting for his partner to get up on a ledge. P2 is confused about what to do and P1 becomes impatient, eventually reaching over to press P2's controller buttons to create a portal without saying anything. P2 then points at the screen to try and encourage P1 to create the second portal and walk through. When P1 is unable to do this, P2 takes the controller away to perform the action. During the whole process, P1 looks visibly disinterested and is no rush to get the controller back. Despite the fact that this strategy led to progress, this example shows how being told what to do and losing control is likely to lead to an involvement breakdown.

Discussion

Similar to Study 1, the findings show how one strategy led on to another but also how different strategies were used by each participant within a pair. For instance, while working on the same problem one player may have been engaged in *Trial & error*, whilst the second player would be using *Stop & think* to observe them and subsequently formulate a possible solution through *Experiment*, before communicating this back to the first player through *Knowledge exchange.*

Interestingly, the findings also indicate how involvement breakthroughs can be achieved through testing the limits of the game. In addition to the players jumping through portals together in Session 1 (Mixed), in Session 2 (Expert) the pair attempted to shoot each other with lasers (P2: "I expect you to die Mr.Bond!"). P2 also teases P1 by repeatedly stepping on and off a button to briefly open a door but not for long enough to walk through. Again, while these types of breakdowns are not engineered by the game, they illustrate how playing around with the mechanics can lead to an increase in involvement. Though perhaps in some cases for only one of the players!

In Study 2, a recording of the game-play video was not played back to the participants as the dialogue between the players was considered a rich source of data. While the dialogue was helpful for developing the cooperative strategies, the lack of insight into players' internal thought processes meant it was sometimes hard to code for the previously established strategies e.g. a player may have been using *Experiment* but unless they verbalized this to their companion it was difficult to pinpoint. Nonetheless, there were still examples within the data of all the categories that were developed in the previous study. This point is raised however as a caution to those who would like to attempt a quantitative comparison of the categories and how often different types of players used each strategy on the basis of observation and the conversational data.

GENERAL DISCUSSION AND CONCLUSIONS

There is lack of research on how people adopt different types of strategy as part of learning through gameplay. We addressed this issue by examining the strategies players use to overcome breakdowns and achieve breakthroughs. Given that learning is often a social process, the initial set of strategies was applied and extended to account for cooperative play. The result is a set of eight strategy types; three of which apply only within cooperative games, while five apply to both single and multi-player games.

The strategies adopted by players are likely to relate to the type of game being played (or even to particular sections of the same game), as well as their level expertise. To account for a range of player behavior, both studies included players of different ability levels. Study 1 recruited hardcore and casual players and asked them to play a game they had not played before. Study 2 recruited players who differed in terms of their experience with the *Portal* series. However, expertise can be difficult to define in the context of gaming. Does expertise relate to gaming in general or one game specifically? There is scope for further research to examine the impact of different types of expertise in relation to strategy choice and progress. The challenge for designers is how to support players with different levels of ability while avoiding major involvement breakdowns that lead to players quitting the game altogether.

The findings of the studies indicate multiple strategies are often employed to achieve a breakthrough in single-player and multiplayer games. For single players, one strategy would lead on to the next (sometimes quite rapidly). In a multiplayer co-located context, players would use different strategies at the same time e.g. P1 would *Stop & think* to observe P2 as they offered *Guidance* or P2's *Knowledge exchange* would lead to P1 to *Experiment* etc.

Regarding each of the strategies, *Trial & error* has been referred to in other studies [1; 4; 30], though it is not always clearly defined. In Gee's analysis of games [8], he describes how players are continually probing the game-world, reflecting on actions, forming a hypothesis, testing through re-probing and then accepting or rethinking their initial hypothesis. However, the *Trial & error* strategy indicates that there are times when players are more playful and haphazard; trying out actions just to see what, if anything, will happen and sometimes just for fun. Unlike Gee's "Probing principle" suggests [8], an explicit hypothesis is not always formed. However, in *Experiment*, the player does need to have a more developed understanding about the game-world in order to be able to test it.

In terms of design considerations, the distinction between these two strategies is particularly important to consider in relation to educational games where it is key to ensure that there is an alignment between the game mechanics and the intended learning [10; 11]. While *Trial & error* may lead to progress, subsequent understanding is not guaranteed, and progress in itself is not an indication of learning [16; 21]. Essentially, designers should avoid situations where action breakdowns lead to progress without understanding breakthroughs.

A further consideration relates to the need to ensure that players are given an opportunity to *Repeat* actions either in a safe part of the game, or in terms of allowing for gradual improvement of skills throughout the game e.g. through a tutorial. As suggested by Gee [8], players should be able to take risks in game sections where the consequences of failure are minimal. However, consideration should also be given to when the same actions are repeated several times but do not lead to progress e.g. through providing advice to the player about the strategy they are using when they seem stuck after a certain time limit.

In addition, *Stop & think* should be supported and encouraged as reflection is an integral component of the learning process [8; 28]. Though the studies took place outside of a home context, the fact that the information sheets provided were consulted (if only occasionally) as part of *Stop & think* highlights the fact game information can be distributed across modalities and that players do look outside a game for help. There is scope for designers to consider how to provide further information to players or ways in which the game itself can suggest strategies to players who are taking a long time to progress.

Knowledge is also distributed across players, as the cooperative strategies indicate. These strategies do echo some of the Cooperative Performance Metrics presented by El-Nasr and colleagues [7]. Like "Worked out strategies", *Knowledge exchange* represents how player discuss the game-play with each other while *Guidance* relates to "Helping each other". However, these strategies should be viewed in relation to others such as *Experiment* and *Stop & think* to understand how players move from individual actions to cooperative behaviors. Furthermore, the CPMs are presented as a way to evaluate good design practice rather than as a tool for discussing how learning taking place during game-play through achieving breakthroughs.

However, while *Guidance* did seem to be a useful strategy to players, there was no guarantee that players would actually take the advice they were given. Arguably, such interactions show that players are in control of constructing their own learning environment as and when required [30]. An inability or unwillingness to carry out the instructions would occasionally lead to *Surrendering control/Taking over* though this was quite rare.

The *Surrendering control/Taking over* strategy is not necessarily a negative when the surrendering is voluntary and learning occurs as part of observation during *Stop & Think*. However, learning may not always result from this action and the non-active player is likely to experience an involvement breakdown due to not feeling responsible for subsequent progress [16]. One possible way to avoid this is to provide mechanisms that allow for a kind of "Quantum Leap" mode (Quantum Leap was a TV show where the main character would jump into the body of someone else and live their lives for a short period of time). This mode could offer a temporary switch in control of avatars, to allow the more experienced player to demonstrate the solution but without the action being permanent. The less experienced player would thus get a chance to observe the action, get an explanation, and most importantly, carry out the action themselves once control is given back. Thus, the player could consolidate a breakthrough by developing the procedural skills they require, without losing any agency.

Through considering these strategies, we argue that designers can produce experiences which are able to support both learning and player involvement. Furthermore, the strategies can also help develop games that appeal to a broad audience since they account for the ways in different types of players respond to a variety of challenges. Though players with varying levels of expertise were included in studies, to capture a range of behaviors and develop the categories, a consideration of how expertise impacts patterns of strategies, and how social dynamics influence strategy choice was beyond the scope of this research.

In addition, while the studies covered more than one type of game, further research is required to establish the extent to which the strategies apply to other genres e.g. role playing games. While the strategies were applied and developed in relation to co-located multiplayer games, they do not cover online play or competitive contexts (e.g. they do not account for sharing of resources in games like *World of Warcraft*). Finally, future work could investigate how strategies are combined in different ways and further examine the strategies in more depth e.g. by looking at hypothesis formation within *Experiment* in terms how knowledge transfers from the real world, from other games and/or from the same game.

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